UNIVERSITY OF CALIFORNIA.

AGRICULTURAL EXPERIMENT STATION.

BERKELEY, CAL.

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BULLETIN NO. 100.

INVESTIGATION OF THE CATTLE FOODS OF CALIFORNIA.

NOTE.—Hitherto the efforts of this station in the interest of stockgrowers have been mainly confined to the introduction trial and distribution of grasses and forage plants suitable to arid lands. This seemed the most pressing need, and was continually enforced upon us by our correspondents. The popular demand has also been shown by the eagerness with which offerings of seeds and roots of promising grasses and forage plants have been accepted by people in all parts of the State. It has always been our intention to supplement this effort with chemical examination of all available feeding materials in order that Californians might avail themselves of scientific methods in selection and compounding of animal foods which have been demonstrated to be of such wide practical advantage at the East and in Europe, and have been so generally adopted by progressive stockgrowers. Owing to the pressure upon our laboratory force and facilities by investigations in other lines previously begun, it has not been possible, until recently, to enter upon this line of work. It is now hoped to pursue it regularly and systematically.

The statement which is given by Mr. Jaffa in this bulletin is introductory to more direct applications of analyses to practical use which will follow. The subject is in its nature somewhat technical, but is in its essential features readily mastered by any intelligent animal-feeder who will give his attention to it.

As Mr. Jaffa states, we need many more analyses before we shall possess full data to enable us to give satisfactory advice to those seeking to know what materials they can use to produce desirable results most economically, and in what proportions such materials should be used in practical feeding for different purposes. To this end we invite samples of forage plants, or field vegetables, in a green state, of hays of all kinds, and of millstuffs or other byproducts which may be available for cattle food. Such samples should be sent by express addressed "Agricultural Experiment Station, University of California, Berkeley, Cal." Samples should be of about five pounds weight, and should be accompanied by full descriptions of their nature, origin and market values. E. J. WICKSON.

The great aim of chemical analysis of feeding stuffs in general, is to ascertain the amounts of the different nutrients contained in the food; and the object of rational feeding is to use the results so gained in a practical, economical and scientific manner.

As this is the first report of our State Ex-

*Absent on leave, 12 mos., from June 15, 1892.

periment Station on the subject, it will be proper to give a brief review of the history of such investigations and an explanation of the terms used.

The first experiments in this direction were made in Germany a little more than 30 years ago, by Bischoff and Voit, in Munich, Stohman and Henneberg in Weende, and Wolff in Hohenheim, and it is due to these men that rational feeding has advanced to the great extent it has in the present day.

The subject was first prominently brought to notice in the United States in an address before the Connecticut Board of Agriculture in 1873, by Prof. W. O. Atwater, now director of the Storrs School Agricultural Experiment Station, Storrs, Conn., the annual reports of which contain most valuable and interesting information, and from which some of the data herein given have been obtained.

In regard to cattle foods the German feeding standards, and methods of computing rations are in common use all over the eastern States, and we trust that it will not be long ere the same will be in vogue here. But owing to the great differences in climate and harvesting conditions between California on the one hand, and the East and Europe on the other, it becomes imperative with us to make complete investigations of all the different food materials as they exist here, in order that we may proceed intelligently in the making up of rations.

While chemical analysis and investigation can do and have done much toward helping and guiding the farmer and dairyman, they cannot at the present time accomplish all that could be desired.

Grave errors may arise by following too closely the standards and rations set down by chemical researches alone, without taking into account the local circumstances, the individual needs of the animals and the purposes for which they are fed, whether for milk or for fattening for market or for work, as well as the variations of the feeding stufis themselves. Yet, without any knowledge of the composition of the substance fed, the farmer is not only in the dark as to the benefit to be derived from the food, but is also ignorant as to the actual amount necessary, thus wasting at times considerable valuable material.

Nutritive Ingredients of the Food.—The sustaining of the animal body in all of its varied requirements is done by the nutritive ingredients or nutrients of the food, which comprise protein, fat, carbohydrates and mineral matters: the latter, in estimating food values, are not considered, not because they are not necessary, but for the reason that nearly all food, no matter of what description, contains a sufficient supply of mineral matter.

When investigating the amount of ingredients withdrawn from the soil by the crops from which the foods are derived, the ash or mineral contents is the all-important part.

Protein, derived from the Greek, signifying "to take first place," contains all the nitrogenous compounds of the food, and consists chiefly of albuminoids, such as the albumen of the egg, the myosin of lean meat, gluten of wheat, casein of milk, the gelatinoids of the bones and tendons, etc. Besides the albuminoids there are other nitrogenous matters, chief among which is the class termed amides, which are found to a greater or less extent in all foods, more particularly those of vegetable origin.

"In vegetation the amides appear as intermediate stages between the mineral or inorganic matter in the shape of ammonia salts, and the organic constituents or albuminoids. They are, on the one hand, formed in the growing plant from the ammonia salts by a constructive process and from them or by their aid probably the albuminoids are built up; on the other hand, in the animal body they are the stages through which the elements of the albuminoids pass in their reversion to purely mineral matter."

"In germinating seeds and developing buds the amides probably combine both these offices, in being first formed in the germ from the albuminoids in the seeds, entering the young plant or shoot, and in being reconstructed into albuminoids. Their full solubility in water and their ability to penetrate moist membranes adapt them for this movement. They temporarily accumulate in the seedlings and buds but disappear to a great extent as the plant matures, albuminoids taking their place, in which transformation they require the aid of the carbohydrates." (*Johnson*.)

The amide per centage of the total nitro-

gen contained in foods, varies from less than one per cent. in some meals up to as much as 40 in some of the green fodders, and in some varieties of beets used as feeding material, as much as 50 per cent. of the total nitrogen is non-albuminoid. The amides are not considered as valuable as the albuminoids in their nutritive effect, in that they are, similarly to the carbohydrates, conservers of the albuminoids.

The nitrogenous compounds of the food are generally for the above reasons, reported as *crude protein.*

The albuminoids (or crude protein) in the different food materials are estimated from the nitrogen by multiplying the figure for the latter by 6.25, nitrogen being 16 per cent. of the albuminoids. In England the factor used is 6.33 in place of 6.25.

Use of Protein.—The protein being the only nutrient containing nitrogen, has for its principal function the formation of the nitrogenous ingredients of the blood, bone, hair, muscles, skin, tendons, etc., because as far as is known no albuminoids are formed in the animal body otherwise than by the transformation of similar bodies presented to it from external sources.

The protein can be transformed into fats and may serve as fuel.

Fat.—The term fat includes the butter of milk, the fat of meats, oil of seeds, wax of plants, etc. It is determined by treating the perfectly dried substance with ether; the extract thus resulting being designated as crude fat. As might be supposed, these ether extracts have different nutritive values, the fats from the green fodders being of less value than that from the meals and seeds. Some authorities in estimating the nutritive effects of food, give to all the fats the same significance.

The use of fat is mainly for a fuel supply, although it may form fatty tissue, but not muscle.

Carbohydrates.—The carbohydrates, commonly called "Nitrogen Free Extract," on account of their containing no nitrogen, consist of starch, sugar, gums, etc., and fiber. The latter, in the statement of the analyses of cattle foods is reported separately, while the remainder of the above are, in order to conform to the general usage, classed together under the head of "Nitrogen Free Extract." The gums play only a secondary part as regards the nutritive values of foods.

The carbohydrates are transformed in the body to fats and consumed as fuel. The latest experimental evidence goes to prove that protein, carbohydrates and fat may directly or indirectly be transformed into the fats of milk.

The mineral matters or ash of the food materials consist chiefly of lime, potash and phosphoric acid with varying amounts of sodium, magnesia, iron, sulphuric and chlorhydric acids, silica, etc.

These ingredients have important functions to perform in the animal body and, as previously stated, exist in sufficient quantities in all foods.

Digestibility of Feeding Stuffs.—The chemical composition of the food material alone is not of much value to the farmer if he does not know how much of each nutrient for the feeding stuff in question is digestible. In all foods there is always a certain portion of each nutrient which is not digested in its passage through the body.

In order to ascertain how much is digestible the food is weighed and analyzed before consumption, and the animal excrement similarly treated. The difference between these two analyses is taken as the quantity digested.

The results so obtained are only approximate, but in the present state of such researches the best data attainable. They are termed "digestion coefficients." To illustrate the above:

In every 100 pounds of the sample of alfalfa analyzed
there are 7.96 crude protein
1.40 crude fat
8.28 nitrogen free extract
35.12 crude fiber.

For this hay it has been found that of the protein about 75 per cent is digestible, of the fat 48 per cent, of the crude fiber 46 per cent and about 68 per cent of the nitrogen free extract can be digested. Hence in 100 pounds of the alfalfa there would be—

5.97 lbs. digestible protein
.67 " " fat
26.03 " " nitrogen free extr. } carbohydrates
16.15 " " fiber }

In a similar manner are obtained the results given in the table below.

For each food material the digestion coefficients vary to some extent. For instance, while about 57 per cent of the protein is digestible in oat hay, 78 per cent is so in the case of wheat middlings or bran.

Nutritive Ratio.—The nutritive ratio is the proportion between the digestible protein or nitrogenous matters of the food and the non-nitrogenous part, or the fats and carbohydrates. Thus, in alfalfa,

The digestible protein is 5.97	
" " fat x 2.5 "	1.68
" " fiber "	16.15
" " nitrogen free extract	26.03
	43.86

Forty-three and eighty-six hundredths divided by 5.97 gives 7.3, which is the nutritive ratio. When estimating this ratio the figure denoting the amount of digestible fat is multiplied by 2½, because it has been found by experiment that there is about 2½ times as much heat in a pound of fat as there is in the same quantity of carbohydrates.

Feeding Standards and Rations.—A feeding standard is the quantity of food required per day by the different classes of animals. The standards commonly in use in this country are the ones adopted by the German investigators in this subject, notably Dr. E. Wolff, by whom the following table has been worked out:

POUNDS PER DAY PER 1000 POUNDS LIVE WEIGHT.

	Total organic or dry matter.	Protein.	Carbohydrates.	Fat.	Nutritive ratio.
Horse at light work	21.0	1.5	9.5	.40	1:7
Horse at average work	22.5	1.8	11.2	.68	1:7
Horse at hard work	25.5	2.8	13.4	.80	1:5.5
Oxen fattening, 1st period	27.0	2.5	15 0	.50	1:6.5
Oxen fat'g, 2d period	26.0	3.0	14.8	.70	1:5.5
Oxen fat'g, 3d period	25.0	2.7	14.8	.60	1:6.0
Milk cows	24 0	2.5	12.5	.40	1:5.4
Sheep wool producing (coarser breeds)	20.0	1.2	10.3	.20	1:9.0
Sheep wool producing (finer breeds)	22.5	1.5	11.4	.25	1:8.0
Sheep fattening, 1st period	26.0	3.0	15.2	.50	1:5.5
Sheep fat'g, 2d period	25.0	3.5	14.4	.60	1:4.5
Swine fat'g, 1st period	36.0	5.0	27.5		1:5.5
Swine fat'g, 2d period	31.0	4.0	24.0		1:6.0
Swine fat'g, 3d period	23.5	2.7	17.5		1:6.5

A ration is the amount of food consumed by an animal in one day, or 24 hours. The use of the above table in the estimation of rations therefrom is a simple matter. But this, and a discussion thereof, will have to be deferred until we have a greater number and a more complete set of analyses of California food materials upon which to base our calculations.

Potential Energy.—The measure of food, as regards its fuel value, is made in terms of potential energy, the unit of which is the calorie or the amount of heat necessary to raise the temperature of a kilogram of water one degree Centigrade or one pound of water four degrees Fahrenheit. Instead of this unit we may use a unit of mechanical energy, the foot ton, which is the force that would lift one ton one foot, one calorie being equal to about 1.53 foot tons.

Recent experiments have been made with animals in the respiratory apparatus to learn the proportions in which the several classes of nutrients replace each other as fuel for the body. At the same time, experiments have been made with the calorimeter to determine the heats of combustion of the same materials.

The results so obtained agreed very well with those from the direct experiment with the respiratory apparatus, and they also proved that the different nutrients replaced each other according to their heats of combustion.

Prof. Rubner found, in experiments made in the physiological laboratory at Munich, the quantities of materials which were equal to 100 of fat to be as follows:

Nutritive Substances, Water Free.	As Determined by Direct Experiments with Animals.	As Determined by Calorimeter.
Myosin	225	213
Lean meat	243	235
Starch	232	229
Cane sugar	234	235
Grape sugar	236	235

Taking the ordinary food materials as they come, the following general estimate has been made for the average amount of energy in one gram of each of the classes of nutrients:

POTENTIAL ENERGY IN NUTRIENTS OF FOOD.

	Calories.	Foot Tons
In one gram protein.............	4.1	6.3
In one gram fats....................	9.3	14.2
In one gram carbohydrates...	4.1	6.3

These figures mean that when a gram of fat is consumed, be it fat of the food or body fat, it will, if its potential energy be all transformed into heat, yield enough to warm 9.3 kilograms of water one degree Centigrade, or if it be transformed into mechanical energy such as the muscles use to do their work, it will furnish as much as would raise one ton 14.2 feet or 14.2 tons one foot. The potential energy of the protein or carbohydrates is less than one-half that of the fat.

The potential energy is very simply calculated by the use of the above figures. The amount digestible of each of the nutrients is ascertained, then for each gram of protein so found there will be 4.1 calories of potential energy, similarly for carbohydrates, and for each gram of fat 9.3 calories. A much more convenient mode of calculating the potential energy is to estimate it for the pound of the food used. This is done by supposing each per cent of each nutrient to represent .01 of a pound, which is equivalent to 4.53 grams. Hence in .01 pounds protein or carbohydrates there will be 18.6 calories (4.53×4.1). .01 pound fat will yield 42.2 calories (4.53×9.3).

Let us apply these figures to the sample of alfalfa which contains 5.97 per cent of digestible protein, .67 of fat and 42.18 of carbohydrates. The potential energy for the protein in one pound would be 111.04 calories (5.97×18.6); for the carbohydrates 784.55, and the fat in one pound would yield 28.27 calories ($42.2 \times .67$); the total potential energy in one pound amounting to 923.86 calories.

The use of the above data gives a means of simplifying the calculations of the rations when the sum of the calories and the necessary amount of protein are known. The fat and carbohydrates can replace each other to some extent in any ration, that is, one may be increased and the other diminished, provided the sum of the calories of potential energy remain constant.

In the table below are given the results of the analyses of California cattle foods, so far obtained, and also for the purpose of comparison, the analyses of some of the same food materials, taken mainly from Experiment Station Bulletin No. 11, of the U. S. Department of Agriculture, by E. H. Jenkins, Ph. D., and L. Winton, Ph. B.

All of the samples of California fodders examined were sent by Mr. W. P. A. Brewer, of San Mateo, except the *Lathyrus sylvestris* grown on the University grounds, and the two specimens of wild hay from the land of Mr. J. W. Shanklin, Lassen County.

In Bulletin No. 99, just issued, the green fodder *Lathyrus sylvestris* was fully described. It differs slightly in composition from the sample grown and analyzed in England, in that it has more protein, but less fat and nitrogen free extract than is found in the English specimen, this being due, in all probability, as has been stated, to the different stages at which the plants were cut. It is a very valuable forage plant, and a better appreciation of its nutritive value will be had by comparing it, in the form of hay, with the first-quality oat hay. It will be seen from the table that it contains 20.16 per cent of crude protein, which is about two and one-half times as much as found in the oat hay. The crude fat percentage is also much higher, as indicated by the figures 4.02 as against 2.80 for the oat hay. An inspection of the amounts digestible in the two foods renders the contrast still more striking, for the reason that in the vetches, to which the *Lathyrus sylvestris* (flat pea) belongs, the digestion coefficients of protein and fat are greater than in the case of oat hay.

There are in every hundred pounds of the *Lathyrus sylvestris* 15.32 pounds digestible protein, being more than three times the amount (4.74 pounds) contained in every hundred pounds of oat hay. The digestible fat, 2.41, is nearly double 1.34, the figure for the oat hay. The nutritive ratio is very much closer than that of the oat hay. In the *Lathyrus sylvestris* there is one part of

COMPOSITION OF THE FODDERS.

	Number of Analyses	ORIGINAL SUBSTANCE. Percentage Composition. Moisture	Pure Ash	Crude Protein	Crude Fiber	Nitrogen Free Extract	Crude Fat	Amount Digestible in 100 Pounds. Crude Protein	Crude Fat	Crude Fiber	Nitrogen Free Extract	Potential Energy in One Pound (Calories)	Nutritive Ratio
GREEN FODDERS.													
Lathyrus sylvestris (Cal.)	1	63.48	3.18	8 18	9.76	13.77	1.63	6.23	.93	5.27	8.94	422	1: 2.4
Lathyrus sylvestris (England)	1	58.63	3.09	7.44	12.21	16.58	2.05	5.65	1.23	6.59	10.78	480	1: 3.6
HAY.													
Lathyrus sylvestris (Cal.)	1	10.00	7.83	20.16	24.05	33.94	4.02	15.32	2.41	13.94	22.06	1,070	1. 2.7
Oat Hay, first quality (Cal.)	1	10.38	6.75	8.31	23.85	47.91	2 80	4.74	1.34	13 83	29.70	954	1: 9.9
Oat Hay, second quality (Cal.)	1	9.80	7 24	6.57	25.75	48.54	2.10	3.74	1.00	14 93	30.09	949	1:12.7
Oat Hay (Eastern)	2	9.15	6.48	8.85	28.07	44 71	2.74	5.04	1.32	16.28	27.72	968	1: 9.4
Alfalfa Hay (Cal.)	1	12.18	5.06	7.96	35.12	38.28	1.40	5.97	.67	16.15	26.03	925	1: 7.3
Alfalfa Hay (Eastern)	21	8.44	7.44	14.28	25.01	42.68	2.15	10.71	1.03	11.50	29.02	977	1: 4.0
Burr Clover Hay (Cal.)	1	11.25	6.91	10.50	26.19	44.92	2.23	5.99	1.29	11 79	27.90	942	1: 7.1
Wild Hay, Eleocharis palustris (Cal.)	1	11.55	7.66	5 69	22.27	51.18	2.65	2 89	1.06	11.36	31.73	900	1:15 7
Wild Hay, Atropis Californica (Cal.)	1	10.10	6.82	5.30	27.34	48.44	2.00	2.65	.80	13.94	30.03	901	1:17.3
BY-PRODUCTS AND MEALS.													
Wheat Middlings (Cal.)	1	11.29	4.01	18.33	5.55	55.77	5.05	14.29	3.48	1.39	42.94	1,231	1: 3.7
Wheat Middlings (Cal.)	1	12.36	3.14	14.43	4.15	61.80	4.12	11.26	2.84	1.04	47.58	1,262	1: 4.3
Wheat Middlings (Eastern)	32	12.10	3.29	15.62	4.60	60.42	3.97	12.18	2.73	1.15	46.51	1,228	1: 4.1
Wheat Bran (Cal.)	1	11.06	6.42	15.49	8.57	54.21	4.25	12.42	2.93	2.14	41.74	1,169	1: 4.1
Wheat Bran (Cal.)	1	11.97	6.44	12.77	9.28	55.49	4.05	9.96	2.79	2.32	42.72	1,141	1: 5.2
Wheat Bran (Eastern)	88	11.91	5.78	15.42	8.99	53.87	4.03	12.03	2.78	2.26	41.47	1,152	1: 4.2
Linseed Meal, old process (Cal.)	1	9 35	5.22	29.75	6 23	31.20	18.25	24.39	16.61	1.25	22.77	1,670	1: 2.7
Linseed Meal, old process (Eastern)	21	9.16	5 72	32.93	8.88	35.40	7.91	27.00	7.20	1.78	25.72	1,317	1: 1.7

digestible protein or albuminoids for every 2.7 parts of non-nitrogenous matters, while in the oat hay there is only one part protein for every 9.9 parts non-nitrogenous.

A comparison of the analysis of the first-quality oat hay (grown here) with that from the East, shows a close agreement as regards the ash, the percentages of which are 6.75 for California and 6.48 for the Eastern sample, the protein showing 8.31 and 8.85 respectively, and the fat, the figures being 2.80 as found here and 2.74 for the Eastern specimen.

The same general agreement is seen in the nutritive ratio and potential energy of the two hays.

As might be supposed, the second quality, containing as it does more straw, will naturally have less protein and fat and more crude fiber than the first quality.

The percentages being respectively for the protein—8.31 and 6.57; for fat—2.80 and 2.10; for fiber—23.85 and 25.75.

We must defer making comparisons of California alfalfa with that grown elsewhere until we have more analyses at hand, because the sample analyzed consisted entirely of stems and hence would contain much less protein and fat, and show a far higher percentage of crude fiber than would a representative sample.

It is to be regretted that it was not possible to analyze another specimen in time for this publication.

The burr clover-hay with its 10.50 per cent of crude portein and 2.23 of fat, constitutes a very fair fodder.

The wild hays, *Eleocharis palustris* and *Atropis Californica*, from Lassen county, contain very low percentages of protein, 5 69 and 5.30 respectively, but an average amount of fat, 2.65 and 2.00 representing the amounts found.

The nutritive ratios 15.7 and 17.3 are far from being desirable.

There is very little variation between the analysis of the second sample of California wheat middlings and the average of 32 analyses of the same food material as it exists in the eastern States.

The protein percentages, 14.43 for California and 15.62 for the averages, and the

nitrogen free extract, 61.80 for California and 60.42 for the average, show the greatest differences. The figures for the fat, crude fiber and the ash are quite close.

The first sample of wheat middlings has a greater nutritive value than the second, in that it contains more protein.

A comparison of the analyses of bran presents a case of marked agreement between that of the first sample of the California substance and the average of 88 analyses from the East, as is shown by the following table:

	California Sample.	Average of 88 Eastern Analyses.
Moisture	11 06	11.91
Ash	6 42	5.78
Crude Protein	15 49	15.42
Crude Fiber	8 57	8.99
Nitrogen Free Extract	54.21	53.87
Fat	4.25	4.03

The exceedingly high per cent, 18.25, of crude fat in linseed meal, is owing to the oil not having been properly extracted; it is more than twice the amount, 7.91, obtained as an average for the percentage of fat in 21 analyses, as taken from Bulletin No. 11 of the Department of Agriculture.

The protein percentage in the average is somewhat higher than the corresponding one in the California sample, as shown by the figures 32.93 and 29.75, respectively.

The crude fiber per cent, 6.23, and the nitrogen free extract, 31.20, contained in the California sample, are also lower than the per cents found for the same ingredients in the above-named average. The ash contents do not differ materially in either.

It will be thus seen that so far as examined, where representative samples have been used, the California products compare quite closely with those of the eastern States.

M. E. JAFFA.

Berkeley, Feb. 12, 1893.